A Possible Model of Ur-baryons*

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Abstract :

A possible model of ur-baryons is proposed based on the analogy to the "existence form" of magnetism in nature.
The three kinds of ur-baryons (or the fundamental triplets) are introduced, which are supposed to be the basic constituents of hadrons. The structures of the low-lying hadron levels and their mutual interactions are discussed in some detail, where some materialistic basis is given for the A-parity introduced by Bronzan and Low. Further the unstability of the ur-baryons, the unification of strong and weak interactions will be pointed out.

I. Various successful applications of U (3) symmetry to stong, weak and electromagnetic interaction phenomena seem to suggest the existence of some kind of ur-baryons with triplet character, which are supposed to be basic entities of the strongly interacting particles, i. e., hadrons. Thus several interesting models[1] concerning ur-baryons have been proposed to understand the realized patterns of hadron structures and their mutual interactions at large.

In this paper, we wish to discuss a possible. approach to the model on ur-baryons.
We start with the cognition that the particles belonging to the spinor representations of U (3) group (charged particles in generalized sense) do not likely exist, as itself, in our neighboring matter, but it can exist only as the composite form belonging to the tensor representations (uncharged particles). To accomadate our scheme with this fact, let us set the following requirements both for the fundamental triplets and their dynamics, without questionning about their reasonability or validity :

a) Triplets have integral electric charge and baryon number.
b) Forces between the basic triplets are, irrespective to their characters, superstrong attractive or superstrong repulsive depending upon

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whether or not they are mutually in the conjugate representations of U (3).

Among various ur-baryon models, the one proposed by Gürsey, Lee and Nauenberg[2] (G. L. N.) satisfies the above requirements.

We wish to extend this model by adding another fermion triplet, for the reason given below : The "form of existence" mentioned before is quite unique and may be found in the relation between the magnet and it's associated two poles (N anb S) under the assumed or fictitious existence of magnetic monopoles.

The basic triplets are, so to speak, just like magnetic monopoles. The strong forces between monopoles (much stronger than the π-N interaction, if it exists at all) may correspond to those of triplets. This means triplets to carry a kind of charge, which will be called the monopole charge (or M charge). The magnetic neutrality of matter corresponds to the existence of M charge neutral particles only. We also note that the two poles (N and S) are symmetric (or permutation invariant) under the absence of magnetic field, which is taken over into our scheme as the "R conjugation".

In closing this section, we shall summarize the above analogy in Table I.

Mag. Monopoles	$\longrightarrow$	ur-baryons	M charge
N		3	1
S		3*	− 1
Chain of N-S Pair		uncharged particles	
N$\longleftrightarrow$S symmetry		"R conjugation"	

Tadle I. Correspondences between magnetism and the proposed ur-baryon model.

II. We now introduce the three kinds of triplets, χ_i, ξ^i (J=1/2) and A^i (J=0 or 1 ; $\overline{A}_i=(A^i)^+$; i=1. 2. 3.), whose quantum numbers are shown in Table II.

B \ M	1	− 1
1	χ^i	ξ^i
0	$\overline{A}_i$	A^i

Table II. B and M denote baryon number and monopole charge, respectively.

As the basic interaction (the constructive force of hadrons) among these triplets, we shall take the following model Lagrangien :

$$L_{int}(1) = -iG_M(\bar{\chi}^i\gamma_\mu\chi_i - \bar{\xi}_i\gamma_\mu\xi^i + \bar{A}_i \overleftrightarrow{\partial_\mu} A^i)M_\mu$$

$$-iG_B(\bar{\chi}^i\gamma_\mu\chi_i + \bar{\xi}_i\gamma_\mu\xi^i)B_\mu,$$

where $\mathbf{M}_\mu$ and $\mathbf{B}_\mu$ are the neutral vector fields coupled superstrongly to M charge- and baryon-currents, respectively.

We may replace Eq. (1) by the appropriate Fermi interaction that gives rise to the required forces given in the preceding section.

We also note the following relations to be satisfied :

$$\begin{aligned} &G_M > G_B \gg g_{\pi N}, \\ &m_M \approx m_B \gtrsim 1\text{Bev}, \\ &M_\chi = M_\xi > M_A \gg M_N, \end{aligned} \tag{2}$$

where $g_{\pi N}$ and M_N mean the ps π-N coupling constant and the nucleon mass, respectively.

The symmetry group of our Lagrangien is U(3)⊗U(3)⊗U(3), which is too large to be attractive. In order to reduce it down to the U(3) symmetry, we introduce the strong interaction of the following form[3] :

$$L_{int}(2) = -\frac{G_S}{M}(\bar{\chi}^i\bar{A}_i\,\xi^i\bar{A}_i + \text{h. c.}), \tag{3}$$

where

$$g_{\pi N} \approx G_S \ll G_M,\ G_B. \tag{4}$$

It is seen from Eq. s (1), (2) and (3) that our theory is invariant under the following replacements :

$$\left.\begin{aligned} &\chi_i \longleftrightarrow \xi^i, \\ &\bar{A}_i \longleftrightarrow A^i, \quad \mathbf{M}_\mu \longrightarrow -\mathbf{M}_\mu \end{aligned}\right\} \tag{5}$$

This invariance is analogous to the NS symmetry mentioned before and will be called the "R conjugation" invariance.

It is to be noted that the "R conjugation" has a clear materialistic basis and that is much restrictive than the well-known one.

The C "R" parity of the bosons (B=0) can be identified with the A number introduced by Bronzan and Low[4], which will be discussed in next section.

III. We shall consider the two-body bound states described by the ur-baryon pair system.

III A) The presence of $L_{int}(1)$ only.

In this case, we obtain highly degenerate hadron levels, as is shown in Table III.

B	Configurations	Space time characters
0	$(\bar{\chi}\chi)_{8+1}$	0^-, 1^-, $({}^1L;\ {}^3L_J, J=L-1, L, L+1)$
	$(\bar{\xi}\xi)_{8+1}$	The same patterns as the above with equal masses for the corresponding ones.
	$(\bar{A}A)_{8+1}$	1) A^j: scalar field 0^+, 1^-, 2^+, ... etc.
		2) A^j: vector field 0^+, 1^+, 2^+, $({}^{2S+1}L_J,\ S=0, 1, 2$ $J=L+S, L+S-1, ..$ $...\ (L-S|)$
1	$(\chi A)_9$	1) $\frac{1}{2}^+$ $(J=L\pm ½)$
		2) (*) $\frac{1}{2}^+$, $\frac{3}{2}^+$ $\left({}^{2S+1}L_J,\ S=\frac{1}{2}, \frac{3}{2}\ \ J=L+S, L+S-1,..(L-S|\right)$
	$(\xi\bar{A})_9$	The same as $(\chi A)_9$ including their masses
2	$(\chi\xi)_9$	0^+, 1^+ $({}^1L;\ {}^3L_J\ \ J=L+1, L, L-)1$

Table III. The hadron levels described by the ur-baryon pair system. The states with non zero angular momentum are shown in brackets.

We have over-simplified the two points in Table III. Firstly the unitary singlets of $(\bar{\chi}\chi)$, $(\bar{\xi}\xi)$ and $(\bar{A}A)$ with the same J^{PG} are actually get mixed such that their eigenstates are the appropriate linear combinations thereof, the masses of these states being different. This is a general feature for the $B=0$ unitary singlets. Secondly the classifications of hadrons by the L, S and parity is not gen-erally true, but the states with different L can be mixed through the tensor force, for example. There would be also extra quantum numbers such as the principal one (n) besides those used in Table III. We note however that the above classifications are approximately correct under the certain limited circumstances.

Let us close this subsection with the remark that $B=2$ system is highly unstable and decays rapidly into the several low-lying hadron levels such as two $B=1$ baryons, two $B=1$ baryons$+$several mesons, etc..

III B) The simultaneous presence of Eq.s (1) and (3).

In this case, the degeneracies among the hadrons consisting of χ and ξ

* We can define the parity of the S state (χA_μ) to be positive.

can be removed and that every U(3)-multiplets have the definite "R parity" in the sense :

$$T^{lmn\dots}_{ijk\dots} \xrightarrow{\text{R-conjuation}} \eta T^{ijk\dots}_{lmn\dots}, \qquad \eta = \pm 1, \tag{5}$$

where $T^{lmn\dots}_{ijk\dots}$ denotes a typical irreducible tensor in the U(3) space.

We give a summary. in Table IV, of the expected lower mass levels (L $=0$ for the fermion pairs and $L \leqslant 1$ for the boson pair) taking the A^j fields to be scalar.

B	Configurations	"R-parity"	Identifications	
0	$\frac{1}{\sqrt{2}}(\bar{\chi}\chi+\bar{\xi}\xi)$	$+1$	π_{8+1}	PS
	$\frac{1}{\sqrt{2}}(\bar{\chi}\chi-\bar{\xi}\xi)$	1	π'_{8+1}	
	$(\bar{A}A)$	$+1$	S_{8+1}	S
	$\frac{1}{\sqrt{2}}(\bar{\chi}\chi+\bar{\xi}\xi)$	$+1$	V'_{8+1}	
	$a(\bar{\chi}\chi-\bar{\xi}\xi)+b(\bar{A}A)$	-1	V_{8+1}	V
	$-b(\bar{\chi}\chi-\bar{\xi}\xi)+a(\bar{A}A)$	-1	V''_{8+1}	
1	$\frac{1}{\sqrt{2}}(\chi A+\xi\bar{A})$	$+1$	N_{8+1}	$J^P=\frac{1}{2}^+$
	$\frac{1}{\sqrt{2}}(\chi A-\xi\bar{A})$	-1	N'_{8+1}	

Table IV. The classifications of the hadrons within the approximation of $L=0$ (0, 1) for χ and ξ pair ($\bar{A}A$ pair).

In Table IV, the primed states and 0^+ states are the predicted ones. 1^+, 2^+ mesons, etc. are also expected for $L=1$ system.
We also note that Bronzan-Low's[4] classifications (using A quantum number) for PS$-8+1$, $V-8$ and $V-1$ are equivalent to take respectively π'_{8+1}, V_8 and V'_1 in Table IV.
We prefer however to take the ones as is suggested in Table IV.

Finally we conjecture the following sequence of mass levels :

$$m_{\pi_8} < m_{S_8} \sim m_{V_8} < m_{\pi'_8} < V_{8'} < V_{8''},$$
$$N_{8+1} < N'_{8+1}, \qquad \text{etc.} \tag{6}$$

III C) Effective Yukawa interactions

We now discuss a few examples of the effective Yukawa interaction among the hadrons given in Table IV.
Before going into details, we note the effective Yukawa interaction to be

derivable, in principle, from Eq.s (1) and (3).

From symmetry considerations, we can obtain the following results :

$$
\begin{aligned}
&\underbrace{\overline{N}'_8 N_8 \pi_8}\,, \quad \overline{N}_8 N'_8 \pi'_8\,, \quad \overline{N}'_8 N_8 \pi'_8 \\
&\text{etc.,} \qquad\qquad\qquad\qquad \longrightarrow \text{D type} \qquad (7) \\
&\overline{N}_8 N_8 \pi'_8\,, \quad \overline{N}'_8 N_8 \pi_8\,, \quad \overline{N}'_8 N'_8 \pi'_8 \\
&\underbrace{V_8 \pi_8 \pi_8}\,, \quad \underbrace{\overline{N}_8 N_8 V_8}\,, \quad \text{etc.,} \quad \longrightarrow \text{F type} \qquad (8) \\
&(V'_8 \pi'_8 \pi_8) = ig\,\mathrm{Tr}\,[\pi'\partial\pi V' - \pi V'\partial\pi' + \pi\partial\pi' V' - \pi' V'\partial\pi],\ \text{etc.} \qquad (9)
\end{aligned}
$$

We see that the well-known interactions shown by $\underbrace{\qquad}$ are consistent with experimental facts.

There are unattractive features however and in fact π'_8 V'_8 becomes stable againt strong interaction, i. e.,

$$
\begin{aligned}
&\pi'_8 \not\leftrightarrow V_8 + \pi_8\,, \quad 3\pi_8 \\
&V'_8 \not\leftrightarrow 2\pi_8\,, \quad V_8 + \pi_8\,, \quad \text{etc.}
\end{aligned}
\qquad (10)
$$

These severe selection rules are consequences of the "R-parity" conservation, so we must make it to relax. We do not think this situation to be a defect of our model at all and indeed we can unify the break-down of the U(3) symmetry and of the "R-parity" conservation on the same level, by considering the interaction of the following form :

$$
\begin{aligned}
&L_{\mathrm{int}}\,(3) = \Delta m\,(\bar{\chi}^3 \chi_3 - \bar{\xi}_3 \xi^3), \\
&\Delta m \approx (1-2) \times 100\mathrm{Mev} \ll M_\chi\,,\ M_\xi\,,\ M_A\,.
\end{aligned}
\qquad (11)
$$

We consider the origin of Eq. (11) to be as deep as that of μ-e mass difference and it exists likely outside the hadron physics[5].

Finally the identifications of the predicted new particles cannot be made at present, but we note that A_1 (1090)[6] and $N^*_{1/2}$ (1480)[6] may be the members of π'_8 and N'_8, respectively.

IV. Concluding Remaks

In the preceding sections, we have developed a possible approach to the ur-baryon model based on the analogy to the existence form of magnetism in nature. Of course, this analogy is one-sided. For example, we could take the one such that just as the magnetic mono-poles are fictious and apparent existence, the ur-baryons with triplet property do not actually exist[7]. What we find and understand in the area of hadron physics are not true reflections of the "reality" of nature, but it is simply an apparent property thereof.

We reject this analogy however, since we have every reasons to believe the existence of the ur-baryns. We simply mention the following point : To consider hadrons of more than one hundred kinds with complex structures to be basic entities of matter and at the same time to take the strict atomism is logically inconsistent.

Now we shall give several remarks. Firstly we have predicted a number of new particles, most of these having the same space time characters as the known ones [Table IV]. This feature is not specific to our model and is generally expected in the multi-triplet ones. Future experimental developments could answer on this point. Secondly we discussed the bound states with the simplest ur-baryon configurations, though the study of many-body configuration is argent as the well known decuplet, for example, is described in 4-body configuration $\chi_i A^j A^k \overline{A}_l$ in our model, which will be discussed in another occasion.

Thirdly in the symmetry considerations, it is a custom to discuss the consequences of the broken symmetry. Unfortunately we cannot present any new results, except the ones mentioned in the end of Sec. III. We also admit that there are much too freedoms, for the break-downs in the multi-triplet models, to give their reasonable and unique discussions. Finally if we take A_i fields to be vector, we can unify strong and weak interactions by introducing the following semi-weak interaction :

$$H_W = iG\Big[\Big\{\bar{\chi}^2\gamma_\mu(1+\gamma_5)\chi_i - \bar{\xi}_i\gamma_\mu(1\pm\gamma_5)\xi^2 + \bar{\chi}^3\gamma_\mu(1+\gamma_5)\chi_i - \bar{\xi}_i\gamma_\mu(1\pm\gamma_5)\xi^3 + \overline{A}_{\alpha i}\overleftrightarrow{\partial}_\mu(A^2_\alpha + A^3_\alpha)\Big\} A^i_\mu + A^1_\mu\,\bar{\nu}\gamma_\mu(1+_5)\nu\Big] + \text{h. c.}, \qquad (12)$$

where the currents are obtained under the guage transformations (assuming Eq. (1) only) :

$$\begin{aligned} \chi &\longrightarrow e^{i\lambda_K(1+\gamma_5)}\chi, \\ \xi &\longrightarrow e^{i\lambda_K(1\pm\gamma_5)}\xi, \\ A &\longrightarrow e^{i\lambda_K}A, \qquad\qquad (13) \\ \lambda_K &: \text{unitary spin matrices.} \end{aligned}$$

Eq. (12) can explain the favorable facts, i. e., the quite massiveness of the weak bosons[8], the octet dominance in the non-leptonic decays, F-type (D-type) for the vector (axial) current taking $1-\gamma_5$ for ξ in Eq. (13) and finally unstability of the triplets. These possibilities will be examined in future.

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